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ABSTRACT

This study of 24 third-grade students learning Logo had 3 major research goals: (1) to compare the effects of learner control with those of program control on students' metacognition, knowledge acquisition, and knowledge application, with total subjects; (2) to extend the comparison between learner control and program control by classifying the total learner control group into two groups according to whether the students make active or passive use of control options, and making comparisons between each of the two learner control groups and the program control group; and (3) to investigate whether results of comparisons between learner control and program control change in relation to students' different levels of prior knowledge of mathematics concepts related to those in Logo. Both groups were introduced to basic Logo commands with definitions, rules, examples, and practice. Students in the learner control group were free to decide whether and how often they needed to review some of the instructional components relative to a practice item, or to skip the review, while the other group received externally controlled computer-assisted instruction in which all control in the lessons was regulated by the program on the basis of predesigned rules. With various supportive variables factored in, the results indicated that learner control seemed to foster students' metacognitive as well as cognitive abilities in a more effective way than program control, regardless of different levels of prior background knowledge of a related subject. Data tables and additional information on the study are presented in three appendixes. (46 references) (BBM)

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Title:

Effects of Different Loci of Instructional Control on Students' Metacognition and Cognition: Learner vs. Program Control

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Overview

This study is an investigation of the effects of different loci of instructional control on students' metacognition and cognition in a computer-assisted learning environment. The loci of instructional control compared in this study are learner and program control over instructional elements in a lesson. LOGO, a computer programming language, is the content area to be taught. Subjects are third-grade students.

This study is intended to provide valuable guidance for the design of educational software. Addressing conflicting issues regarding instructional design strategies may help maximize the potential of computers as educational media.

Need for Research

As sophisticated vehicles for instruction, computers can create highly motivating and dynamic learning environments (Feurzeig, 1988), and present a virtually unlimited range of options to instructional designers and individual learners (Burke, 1982; Gay, 1985). During the last few years, educational technology researchers have recognized the unique and divergent instructional capabilities of computers, and thus have responded by enthusiastically devoting efforts to the improvement of computer education. In such efforts, there has been a great emphasis on systematic methods for designing Computer-Assisted Instruction (CAI), and enhancing the quality of educational software.

The adoption of computers to educational settings has enabled interaction between learners and instructional materials. One of the issues currently attracting researchers' attention in the area of CAI design is the locus of instructional control: should instructional control be given to a learner (learner control), or to a program (program control)?

Most early CAI was designed on the basis of program control with little or no control given to a learner over instructional elements. One of the criticisms of such design is that it is based on the assumption that instructional designers are the best judges of when, where, how much and what kind of instruction is needed to teach certain knowledge or skills (Hannafin, 1984). Learner control, in contrast, is an instructional design strategy that provides a learner with freedom to make key decision(s) about her/his own learning rather than being locked into the elements predesigned by an instructor or instructional designer. Flexibility is the intended outcome of this strategy.

Nunan (1983) contended that knowledge is constructed in the process of learning, that a learner is an intentional agent, and that instructional designers should therefore seek alternative design strategies to reject the "technological philosophy of education" and the "common-sense structure of professionalized design" that have predominated in the area of instructional design. Instead of program control, I propose learner control as one of possible alternatives that place active learners at the center of learning.

In sum, in seeking systematic methods to enhance the quality of educational software, the nondeterministic approach of learner control to instructional design seriously challenges the traditional instructional design paradigm, program control, upon which most CAI has been built (Duchastel, 1986). However, the intuitively appealing assumptions and theoretical arguments regarding learner control have received little support from actual research (Steinberg, 1977; Carrier, 1984; Clark, 1984). The question of whether we need to assign control to a learner or to a program has frequently been asked, but is unresolved. Therefore, it remains as an empirical issue requiring research attention.

Importance of Learner Control in Comparison with Program Control

Advocates of learner controlled instruction have discussed its various advantages. This study will focus on two of the possible benefits of learner control: 1) positive approach to individual differences, and 2) enhancement of metacognition and cognition.

One of the most important benefits of learner control is its positive interaction with individual differences. It is often argued that the unique advantage of CAI is its ability to adapt to the needs of individual students. Theorists and researchers have enthusiastically attempted to design individualized instruction through CAI that can accommodate various types of individuals in educational practice. However, while most people agree with the premise that individual learners are different in ways that influence performance in instruction, there seems to be little agreement about the way in which individualization of instruction should be achieved (Carrier, 1984; Gray, 1987). On this point, research on learner control has begun with the recognition that no one instructional treatment can be best for every learner (Kinzie et al., 1987).

Another important advantage of learner control is

the enhancement of metacognition and cognition through its dynamic learning processes. Unlike program controlled instruction, which aims to improve only products of learning, learner controlled instruction emphasizes processes as well as products of learning. Cognitive psychologists object to the prescriptive characteristics of traditional instructional design under program control, whereby instruction acts upon a learner, as opposed to a learner taking responsibility for her/his own learning (Bonner, 1988).

According to Flavell (1979, 1987), metacognition refers to the active monitoring and consequent self-regulation of one's own cognitive processes, and orchestration of these processes in the service of some concrete goals or objectives. Under learner control, individual learners are in a position to systematically analyze the nature of a task; to monitor and analyze their own understanding of the given task; to select activities that can be performed to accomplish the task; and to actively decide levels or amounts of instruction needed to extend the present knowledge state, while continuously monitoring their own cognitive processes and performances. By being aware of control options and deliberately making decisions about the use of the options under learner control, learners can continuously evaluate their progress towards a given objective and attempt to develop effective learning strategies to achieve this objective. As a result, they can more thoroughly integrate new learning materials within their existing knowledge schema, and enhance metacognitive knowledge and experiences in a more effective way than they would with program control.

In spite of the importance of metacognitive enhancement, instructional designers have not shown much concern for metacognitive development of learners, especially as integrated with subject matter, and this may impose limitations on further progress in understanding learning (Bonner, 1988). Metacognitive enhancement should be considered within educational research and practice as a desired outcome of instructional interventions, along with cognitive enhancement such as achievement. Nickerson et al. (1985) contended that although content specific knowledge is necessary for the best performance, it is not sufficient to guarantee such performance. In fact, as Perkins and Salomon (1989) have asserted, efforts need to be devoted to combining the teaching of subject-matter content and of thinking, as one of the exciting domains of the next decade of educational research and innovation. Learner control is one of the strategies that attempt to combine those two areas.

In short, in carrying out this study, the following theoretical propositions are made: by providing students with control options over a key instructional element and by emphasizing processes as well as products of learning, learner control will accommodate individual differences and influence metacognitive as well as cognitive enhancement in a more effective way than will program control.

PURPOSE

The purpose of the study is to examine the effects of two different loci of instructional control on metacognitive and cognitive enhancement and individual differences, in a computer-assisted instructional environment. There are three major research goals. The first is to compare the effects of learner control with those of program control on students' metacognition, knowledge acquisition and knowledge application, with total subjects. The second goal is to extend the comparison between learner control and program control by classifying the total learner control group into two groups, according to the effectiveness of students' uses of control options (active learner control group and passive learner control group), and making comparisons between each of the two learner control groups and the program control group. The third goal is to investigate whether results of comparisons between learner control and program control change in relation to students' different levels of prior knowledge of mathematical concepts related to those in logo (prior background knowledge). The following figures summarize these three topics:

1) Topic 1 - with total learner control group

X1	O1	O2	O3
X2	O1	O2	O3

X1 - learner control treatment
X2 - program control treatment

O1 - test on knowledge acquisition
O2 - test on knowledge application
O3 - interview on metacognition

2) Topic 2 - with active or passive learner control group

X1	X11	O1	O2	O3
	X12	O1	O2	O3
X2		O1	O2	O3

X1 - learner control treatment with total group
X11 - learner control with active group
X12 - learner control with passive group
X2 - program control treatment with total group

O1 - test on knowledge acquisition
O2 - test on knowledge application
O3 - interview on metacognition

3) Topic 3- with high or low prior background knowledge group

A	X1	O1	O2	O3
	X2	O1	O2	O3
B	X1	O1	O2	O3
	X2	O1	O2	O3

A - high prior background knowledge group
B - low prior background knowledge group

X1 - learner control treatment
X2 - program control treatment

O1 - test on knowledge acquisition
O2 - test on knowledge application
O3 - interview on metacognition

METHOD

Subjects

The study was conducted with a class of 24 third graders enrolled in an urban elementary school in Wisconsin during the fall of 1989. None of the students had previously learned about logo.

Materials

Students in both learner and program control treatment groups were introduced to basic logo commands with definitions, rules, examples and practice. In

practice, students were challenged to hit a given target or aim towards it by changing the turtle's position or heading with the learned command. Two parallel versions of programs were used: one for the learner control group and the other for the program control group. Both versions were delivered by Apple IIe computers along with the posttests. The resulting instructional units for both learner control and program control underwent expert review.

Throughout the instruction, students were able to: 1) identify the screen turtle and the properties of the turtle, i.e. position and heading; 2) recall and use the logo commands for moves that change the position of the turtle in an immediate mode, i.e. FORWARD (FD) and BACK (BK); 3) recall and use the logo commands for turns that change the heading of the turtle in an immediate mode, i.e. LEFT (LT) and RIGHT (RT); 4) predict outcomes of commands and debug commands; and 5) (under learner control) analyze the following: how well do I understand the given command? What don't I know about it? What do I need to review to change the present state of my knowledge?

Treatment

Two types of treatments were employed in this study on the basis of each locus of instructional control: learner control and program control. The former consisted of internally controlled CAI in which students were free to decide whether and how often they needed to review some of the instructional components relevant to a practice item, or to skip the review. In contrast, the latter consisted of externally controlled CAI: all control in the lessons was regulated by the program on the basis of predesigned rules, so that students had no control over instructional components except the instructional pace -- they could advance through the instruction when they were ready.

program control: In the tutorial portion of each lesson, students learned the definition, the rule and four examples of a logo command. Then, four practice items were presented. When a correct response was made, students received positive feedback and moved to the next practice item. When an incorrect response was made, the program provided students with negative feedback and automatically branched them to the review of the definition, the rule and an example of the command under consideration. The review of instruction for practice was presented only after the first wrong answer. Under program control, when students exhibited a lack of understanding of a given logo command, they were guided to review instructional elements relevant to the command. Such repetitive instruction may

reinforce students' understanding of a given topic.

After the review, students had a second opportunity to respond to the practice item. If the answer was still wrong, personalized feedback was presented to show the correct answer, and the next practice item was presented. At the end of the practice session, a total score was displayed.

learner control: The differences between learner control and program control were made only in the presentation of the question for self-estimates of understanding on a given command and in the way in which review was presented after a wrong answer. After the tutorial portion of a lesson, as a part of the treatment, students were asked to rate their understanding of the given command on a four-item Likert scale (1 for 'not at all' and 4 for 'very well'), and to solve four practice items. When an incorrect response was given to a practice item, they were told that their answer was wrong and were continuously advised to think about what they did not clearly understand about the command learned and what they should review. Then, students were allowed to review the instruction for practice, the definition and the rule of the command, or an example of the command, as many times as they wanted to, or to skip the review. Every time they used a review option, a summary of their performance in practice and uses of control options was provided. When students decided not to review any more, a question was presented to confirm if they understood the command well enough to try the practice item again. Then, with confirmation, they had an opportunity to solve the same practice item a second time. When the practice session was completed, a total score was reported along with the students' self-estimates of their understanding of the given command.

In addition, the following factors were integrated into the design of learner controlled instruction, as recommended by researchers and theorists. First, control options were clearly labeled to help students use control options effectively (Reigeluth and Stein, 1983). Second, immediate feedback, continuous advice on students' progress and summaries of their uses of control options were presented to help students make informed decisions about their own learning (Hannafin, 1984; Kinzie, 1988; Lepper, 1985; Lepper & Malone, 1987; Markman, 1977; Merrill, 1984; Tennyson, 1980, 1981; Tennyson & Buttrey, 1980; Waldrop, 1984). Third, students were required to solve a certain number of practice items to assure that they did not bypass important instructional components (Kinzie, 1988; Steinberg, 1977; Waldrop, 1984). Fourth, prior to the instruction, there was a pretraining period to help

students become familiar with the novel learning system with control options, perform conscious cognitive information processing, and acquire declarative (knowing what), procedural (knowing how) and conditional (knowing why and when) knowledge involved in building their own learning strategies (Campbell, 1964; Gay, 1986; Hannafin, 1984; Holmes et al., 1985; Kinzie, 1988; Merrill, 1975, 1984; Schimmitt & Newby, 1985; Steinberg, 1977; Wydra, 1980).

Procedure

Prior to the experiment, on the basis of a mean score on a test on mathematical concepts which are specifically related to logo (e.g. distance and direction), students were identified as belonging to either a high or low prior background knowledge group. Then, in each group, students were randomly assigned to either the learner control or the program control treatment condition. To motivate students, they were informed that although scores on tests would not affect their class grades, their teacher would take a look at their scores. Such information should be presented to stimulate an actual classroom-like incentive that is missing in most learner control studies (Tennyson, 1980; Tennyson & Buttrey, 1980).

The study was conducted over a three-week period with three sessions per week. Each session took about 40 minutes. Before instruction began, there was a pretraining section aimed at help students to become familiar with computers, instructional systems and control options, and to understand the declarative, procedural and conditional knowledge involved in using control options. Then, lessons on logo commands were presented. In each session of instruction, those who finished a lesson earlier than the others were asked to remain in the lab and spend the rest of the session with a paper-and-pencil task on a maze. Upon completion of all instruction, posttests on knowledge acquisition and application and an interview on metacognition were conducted.

Dependent Variables

1) Interview on Metacognition: To serve the major purpose of this study, an adaptation of the Metacomponential Interview developed by Clements and Nastasi (1988) was employed. This interview instrument was developed to assess children's specific executive levels of metacognitive functioning in a mediated situation with aid through a series of prescribed prompts for mediational purposes. Although five metacomponents of the seven proposed by Sternberg (1985) are included in this instrument, in relation to

the learning experience gained through this study, only one metacomponent, monitoring solution processes, was employed in assessing metacognitive effects.

Four questions were presented, with five prompts per question (appendix 3). The number of prompts required for the solution of each question was summed and transformed so that a higher score refers to fewer prompts required and better performance. Further, the transformed scores were summed again over question items. In addition, as Clement and Nastasi directed, the following measures were taken for each question: 1) the number of prompts needed to demonstrate the identification of the fact that something was wrong in presented information and induction (utilization); and 2) the number of prompts needed to answer correctly (correctness). The Cronbach's α reliability values obtained were .53 for utilization and .60 for correctness. The entire interview process was recorded for later analysis and used to test inter-rater agreement in scoring. The correlation values for inter-rater agreement were .87 for utilization and .92 for correctness.

2) Test on Knowledge Acquisition: A 16-item posttest was administered. In the test, items similar to the practice ones embedded in the instruction were presented to explore students' knowledge acquisition. The number of test items on each logo command was equally balanced across all the commands taught throughout the instruction. The Cronbach's α reliability value among the test items for each command was .86.

3) Test on Knowledge Application: Given the length of each side of a square on the screen, students were asked to draw a square by changing the turtle move and turn. In order to avoid any possible confounding effects due to the use of multi-media, both tests on knowledge acquisition and application were delivered by computers along with instruction, and students worked individually with assigned computers.

HYPOTHESES

To serve the purpose of this study, the following hypotheses were examined:

1) The learner control group will show significantly higher scores than the program control group in the tests on metacognition, knowledge acquisition and knowledge application.

2) Significant differences between learner control and program control will be more apparent when the active learner control group is compared with the

program control group than when the passive learner control group is compared with the program control group.

3) For both the group with high prior background knowledge and the group with low prior background knowledge, the learner control group will demonstrate higher scores than the program control group in the tests on metacognition, knowledge acquisition and knowledge application.

DATA ANALYSIS AND RESULTS

Analysis of Variance (ANOVA) methods were utilized in examining the effects of two different loci of instructional control on metacognition (monitoring solution processes), knowledge acquisition and knowledge application.

Total Learner Control vs. Program Control

First, the performance of all students under learner control in the interview on metacognition (utilization and correctness of monitoring) and the tests on knowledge acquisition and application was compared with that of all students under program control, on the basis of an ANOVA. Significant differences were found in both utilization of monitoring and correctness of monitoring (Table 3). Regarding the metacognitive effects due to the treatment, students under learner control showed significantly higher scores in both the utilization and correctness of monitoring than students under program control. On knowledge acquisition and application, students under learner control showed higher scores than those under program control, but no significant difference between the two treatments was found.

Insert Table 3, Figure 3.1 and Figure 3.2 about here

Active or Passive Learner Control vs. Program Control

Then, to permit further investigation of the comparative effects of the two treatment conditions, students under learner control were classified into two groups according to the effectiveness of their usage of control options. An ANOVA was conducted to compare each of the two learner control groups (active and passive) with the total program control group. Effectiveness was evaluated on the basis of the accuracy of the self-estimates of understanding of the logo command taught and the appropriateness of the uses

of control options; the relation between one's rate of understanding on a four-item Likert scale and her/his subsequent performance in practice, and the relation between the number of reviews and the number of wrong answers in practice (appendix 2).

First, to compare the active learner control group with the program control group, an ANOVA was conducted on the four dependent variables (table 4). In contrast with the results of the comparison between the total learner control and the program control treatment groups, a significant difference was found in knowledge acquisition and more significant differences were found in utilization and correctness of monitoring. However, no significant difference was found in knowledge application.

Insert Table 4, Figure 4.1 and Figure 4.2 about here

Second, to compare the passive learner control group with the program control group, an ANOVA method was also utilized with the four dependent variables (table 5). No significant difference was found in any of the dependent variables between the two treatment groups.

Insert Table 5, Figure 5.1 and Figure 5.2 about here

Learner Control vs. Program Control:
With High or Low Prior Background Knowledge Groups

In addition, in order to explore the effects of two different loci of instructional control on individual differences (different levels of prior background knowledge), students were classified into two groups (high or low prior background knowledge groups) on the basis of a test assessing knowledge of mathematical concepts related to logo. For each of the two groups, an ANOVA was conducted to compare the effects of learner control on metacognition, knowledge acquisition and knowledge application with those of program control. Further, an ANOVA method was also used to compare the high prior background knowledge group with the low prior background knowledge group on the accuracy of students' self-estimates of understanding of a given logo command, appropriateness of the uses of control options and effectiveness of the uses of control options.

First, with the students who demonstrated high prior knowledge of mathematical concepts related to

logo, the comparison between the learner control treatment and the program control treatment was made by conducting an ANOVA on the dependent variables (table 6). Significant differences between the two treatment groups were identified, in favor of learner control, in all the four dependent variables: utilization of monitoring, correctness of monitoring, knowledge acquisition and knowledge application.

Insert Table 6, Figure 6.1 and Figure 6.2 about here

Second, with those who demonstrated low levels of prior background knowledge, the comparison between the learner control and the program control treatments was made on the basis of an ANOVA on the dependent variables (table 7). Although the overall performance of the learner control group was better than that of the program control group, no significant difference was found in any of the variables between the two treatment groups.

Insert Table 7, Figure 7.1 and Figure 7.2 about here

Additionally, an ANOVA on the accuracy of self-estimates of understanding, the appropriateness of the uses of control options and the effectiveness of the uses of control options was conducted to investigate any differences between the high and low prior background knowledge groups (table 8). Significant differences were found in all those variables between the two groups, in favor of the group with high prior background knowledge.

Insert Table 8, Figure 8.1 and Figure 8.2 about here

DISCUSSION

In this study, pretraining was provided to both treatment groups in order to help students become familiar with the given learning systems. Supported by this pretraining along with the presentation of clearly labeled control options and a basic requirement to solve a certain number of practice items, students under learner control were asked to estimate their own understanding of the given logo command and make

"informed decisions" in using learner control on the basis of immediate feedback, continuous advice and summaries of their performance and uses of control options.

When these supportive factors were integrated into the design of a learner control study, learner control seemed to foster students' metacognitive as well as cognitive abilities in a more effective way than would program control, regardless of different levels of prior background knowledge of a related subject. The overall performance of the total students under learner control in monitoring solution processes and in recalling and applying learned knowledge was higher than that under program control. In particular, significant differences were found in the assessment of metacognition in favor of learner control. Under learner control, one becomes responsible for her/his own learning, practices conscious reflection on her/his cognitive abilities, task demands and learning strategies, and learns how to manage her/his own thinking processes and learning activities. Thus, one can be led to enhance her/his metacognitive abilities to perform and behave strategically. These learned strategies may be those that transfer to other contexts and facilitate learning activities effectively and efficiently.

Unlike the effects on metacognition, the difference between the learner and program control treatments in the effects on cognition (knowledge acquisition and application) was not statistically significant. However, when an extended comparison between the two treatments was made with the active learner control group that exhibited effective uses of control options, a significant difference was found in knowledge acquisition in favor of learner control. It seems that only when students under learner control can use given control options effectively by making accurate self-estimates of understanding and appropriate uses of control, they can obtain significantly more benefit in enhancing cognition as well as metacognition than students under program control. Although in this study students under learner control demonstrated better performance in the assessment of cognition with aids from supportive factors built into the design of instruction, they still showed different levels of effectiveness in using control options. Further investigation is needed of such supportive factors that can help students use control effectively.

In addition, concerning students' prior knowledge of mathematical concepts related to those in logo, in the learner control treatment group, students who

exhibited relatively high levels of prior background knowledge were significantly more capable of using the given control options than were those with low prior background knowledge. Students with low prior background knowledge tended to estimate their own understanding inaccurately and to review too little. Further, among the students with high prior background knowledge, different effects between learner control and program control were significantly apparent in favor of learner control, in the assessment of metacognition and cognition. However, only slight differences between the two treatments were found among the students with low prior background knowledge, in favor of learner control.

These findings about individual differences in prior background knowledge indicate that students' prior knowledge of a subject matter relevant to the one learned is important in helping them to understand the underlying structure of a given instruction, to develop effective learning strategies and thus to enhance metacognitive and cognitive abilities. As Snow (1980) contended, learner controlled instruction may not overcome the fact that "individual characteristics not under control of the individual will determine to a significant extent what and how much that individual will learn in a given instructional setting" (p.1). Snow argued that research on learner control generally has not proved optimal performance because it is not known which types of learners should be granted control and under which conditions.

In this study, in attempting to find ways to overcome problems that students with low prior background knowledge may have under learner control, supportive factors (pretraining, provision of clearly labeled options and basic requirements, and presentation of feedback, advice and summaries) were integrated into the design of instruction. With these supports, students under learner control exhibited better performance than that of those under program control regardless of their different levels of prior background knowledge. This finding is contradictory to that of some previous research on learner control (Goetzfried and Hannafin, 1985; Hannafin, 1984; Kinzie, 1988; Krendle and Lieberman, 1988; Steinberg, 1977; Tennyson, 1981) which supported the Achievement-Treatment Interaction theory (Tobias, 1976); for students with a low level of prior knowledge, learner control is less effective than program control and for those with a high level of prior knowledge, learner control is more effective than (or comparable to) program control.

It seems that learner control can convey the role

of providing opportunities to improve metacognitive monitoring abilities, while attempting to teach knowledge of specific subject matter content in a more effective way than can program control, regardless of learners' different levels of prior knowledge of a relevant subject matter. However, it should be noted that this study has been conducted with a relatively limited application of control in introductory instruction, and for a short time period. Considering the potentially rich and unique learning environment and experiences that learner control can provide, more research efforts should be devoted to developing instructional models of learner control from which all students can benefit in enhancing metacognitive as well as cognitive abilities.

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APPENDIX 1

Table 1
Total Possible Scores for Metacognition, Knowledge Acquisition and Knowledge Application

variables	total possible score
monitoring: utilization	24
monitoring: correctness	24
knowledge acquisition	32
knowledge application	70

Table 2
Means and Standard Deviations for Metacognition, Knowledge Acquisition and Knowledge Application

variables	total	lc			pc	low	high
		all	active	passive			
monitoring: utilization	10.96 (3.80)	12.42 (4.12)	12.67 (3.20)	12.17 (5.19)	9.50 (2.94)	10.33 (4.31)	11.58 (3.29)
monitoring: correctness	7.21 (4.25)	8.83 (4.45)	10.33 (2.58)	7.33 (5.61)	5.58 (3.50)	6.00 (4.65)	8.42 (3.60)
knowledge acquisition	19.04 (6.92)	21.33 (7.52)	23.33 (7.69)	19.33 (7.47)	16.75 (5.67)	16.50 (6.10)	21.58 (7.00)
knowledge application	46.04 (17.75)	50.42 (17.51)	55.00 (15.49)	45.83 (19.60)	41.67 (17.62)	37.50 (18.28)	54.58 (12.87)

Note: Standard Deviations are presented in parentheses.
lc = learner control treatment group
all = total subjects under learner control
active = the learner control group that showed effective uses of control options
passive = the learner control group that showed ineffective uses of control options
pc = program control treatment group

Table 3
TOTAL LEARNER CONTROL VS. PROGRAM CONTROL:
1) Means and Standard Deviations for Metacognition, Knowledge Acquisition and Knowledge Application
2) F Ratios and F Probabilities between the Treatment Groups

variables	control condition	mean	standard deviation	F Ratio	F Prob.	
monitoring: utilization	lc	12.42	4.12	3.9832	.0585	*
	pc	9.50	2.94			
monitoring: correctness	lc	8.83	4.45	3.9544	.0593	*
	pc	5.58	3.50			
knowledge acquisition	lc	21.3	7.52	2.8384	.1062	
	pc	16.75	5.67			
knowledge, application	lc	50.42	17.51	1.4885	.2354	
	pc	41.67	17.62			

* p<.10

Note: lc = learner control treatment group
pc = program control treatment group

Figure 3.1
LEARNER CONTROL VS. PROGRAM CONTROL
WITH TOTAL LEARNER CONTROL

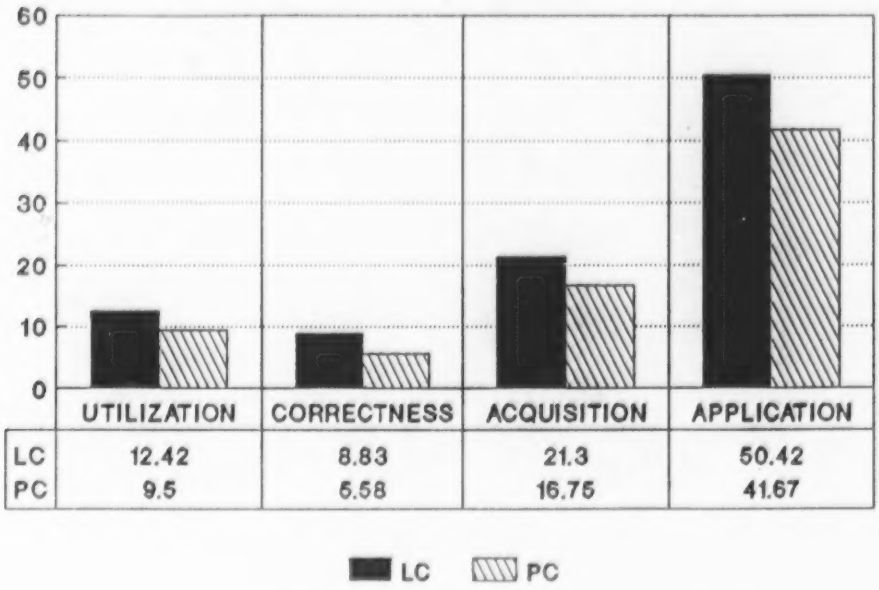


Figure 3.2
LEARNER CONTROL VS. PROGRAM CONTROL
WITH TOTAL LEARNER CONTROL

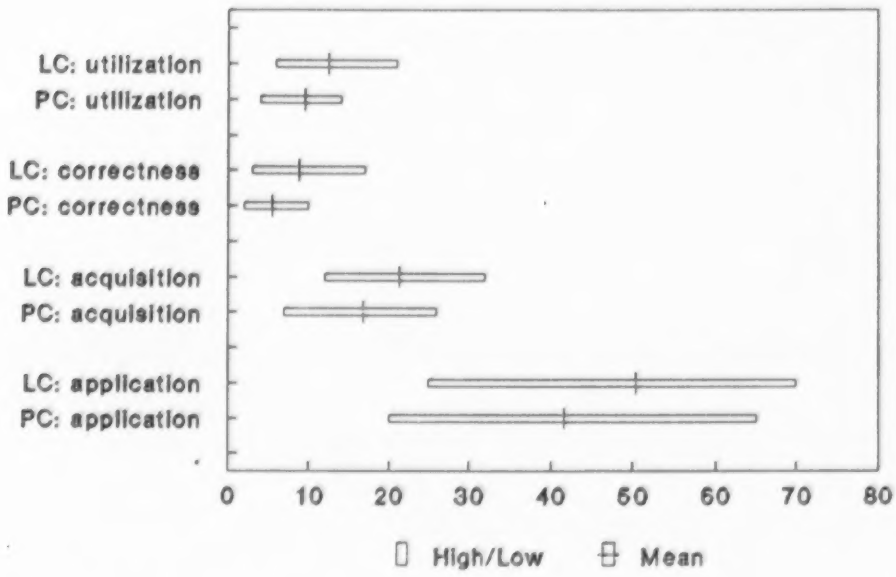


Table 4
ACTIVE LEARNER CONTROL VS. PROGRAM CONTROL:
1) Means and Standard Deviations for Metacognition, Knowledge Acquisition and Knowledge Application
2) F Ratios and F Probabilities between the Treatment Groups

variables	control condition	mean	standard deviation	F Ratio	F Prob.	
monitoring: utilization	lc	12.67	3.20	4.3857	.0525	*
	pc	9.50	3.94			
monitoring correctness	lc	10.33	2.58	8.5800	.0098	**
	pc	5.58	3.50			
knowledge acquisition	lc	23.33	7.69	4.2701	.0554	*
	pc	16.75	5.67			
knowledge application	lc	55.00	15.49	2.4645	.1360	
	pc	41.67	17.62			

* p<.10
** p<.01

Note: lc = learner control treatment group
pc = program control treatment group

Figure 4.1
LEARNER CONTROL VS. PROGRAM CONTROL
WITH ACTIVE LEARNER CONTROL

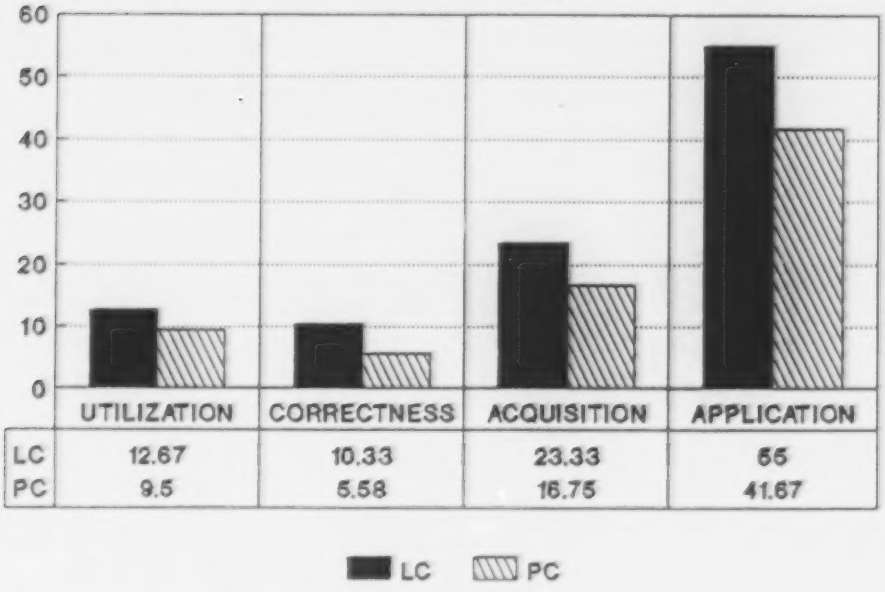


Figure 4.2
LEARNER CONTROL VS. PROGRAM CONTROL
WITH ACTIVE LEARNER CONTROL

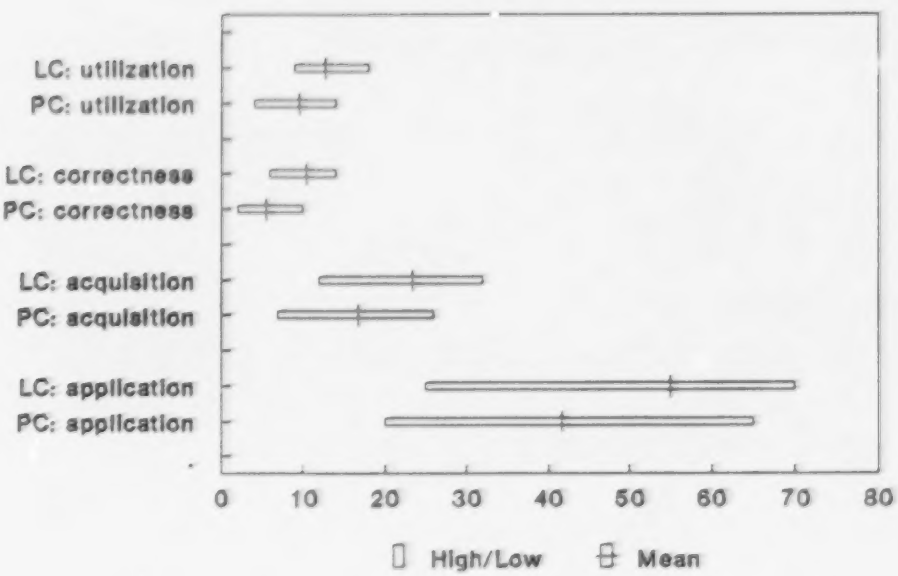
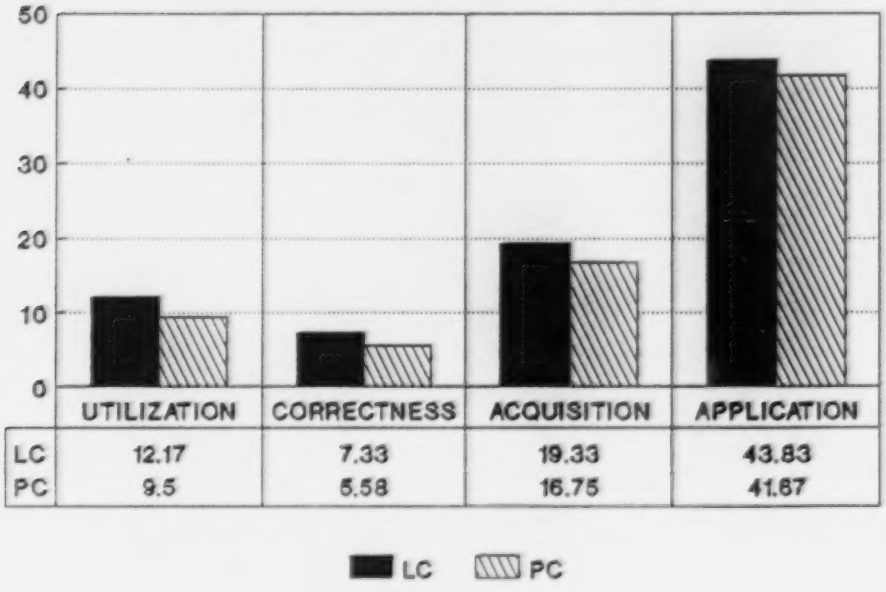


Table 5
PASSIVE LEARNER CONTROL VS. PROGRAM CONTROL:
1) Means and Standard Deviations for Metacognition, Knowledge Acquisition and Knowledge Application
2) F Ratios and F Probabilities between the treatment groups

variables	control condition	mean	standard deviation	F Ratio	F Prob.
monitoring: utilization	lc	12.17	5.19	1.9802	.1785
	pc	9.50	2.94		
monitoring correctness	lc	7.33	5.61	.6707	.4249
	pc	5.58	3.50		
knowledge acquisition	lc	19.33	7.47	.6741	.4237
	pc	16.75	5.67		
knowledge application	lc	43.83	19.60	.2082	.6543
	pc	41.67	17.62		

Note: lc = learner control treatment group
pc = program control treatment group

Figure 5.1
LEARNER CONTROL VS. PROGRAM CONTROL
WITH PASSIVE LEARNER CONTROL



	UTILIZATION	CORRECTNESS	ACQUISITION	APPLICATION
LC	12.17	7.33	19.33	43.83
PC	9.5	5.58	16.75	41.67

Figure 5.2
LEARNER CONTROL VS. PROGRAM CONTROL
WITH PASSIVE LEARNER CONTROL

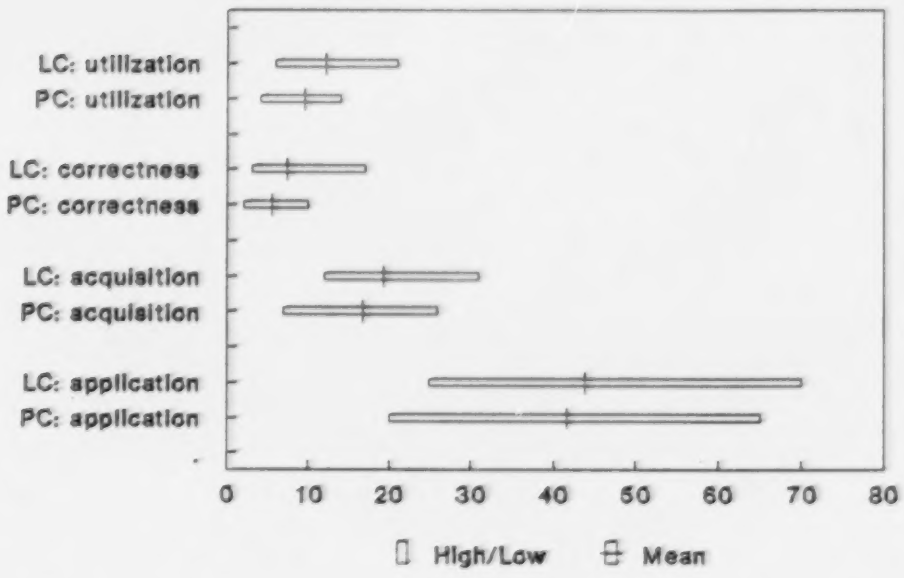


Table 6
HIGH PRIOR Background knowledge GROUP
LEARNER CONTROL VS. PROGRAM CONTROL:
1) Means and Standard Deviations for Metacognition, Knowledge Acquisition and Knowledge Application
2) F Ratios and F Probabilities between the Treatment Groups

variable	control condition	mean	standard deviation	F Ratio	F Prob.
monitoring: utilization	lc	13.17	2.93	3.3865	.0956 *
	pc	10.00	3.03		
monitoring: correctness	lc	10.33	2.58	4.4604	.0608 *
	pc	6.50	3.62		
knowledge acquisition	lc	25.50	5.32	5.1879	.0460 **
	pc	17.67	6.53		
knowledge application	lc	60.83	4.92	3.4615	.0924 *
	pc	48.33	15.71		

* p<.10
** P<.05

Note: lc = learner control treatment group
pc = program control treatment group

Figure 6.1
LEARNER CONTROL VS. PROGRAM CONTROL
HIGH PRIOR BACKGROUND KNOWLEDGE GROUP

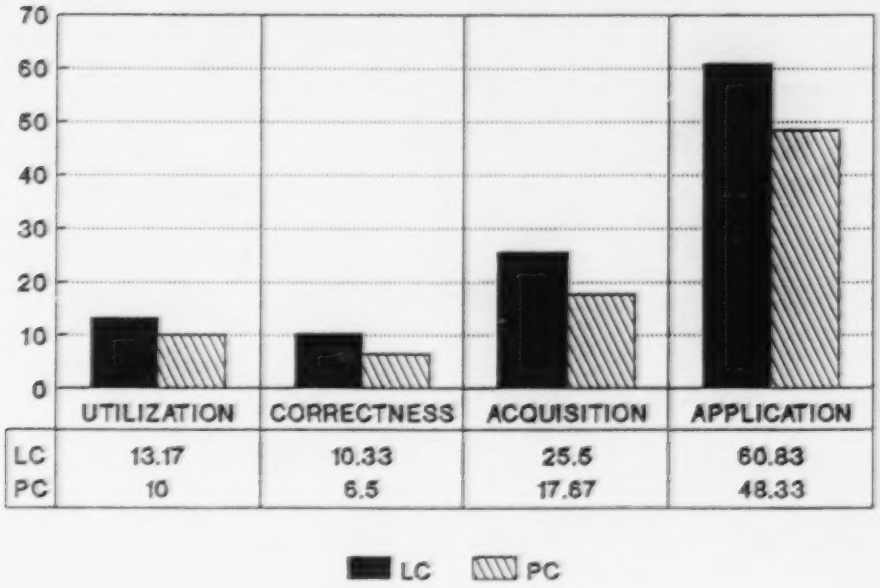


Figure 6.2
LEARNER CONTROL VS. PROGRAM CONTROL
HIGH PRIOR BACKGROUND KNOWLEDGE GROUP

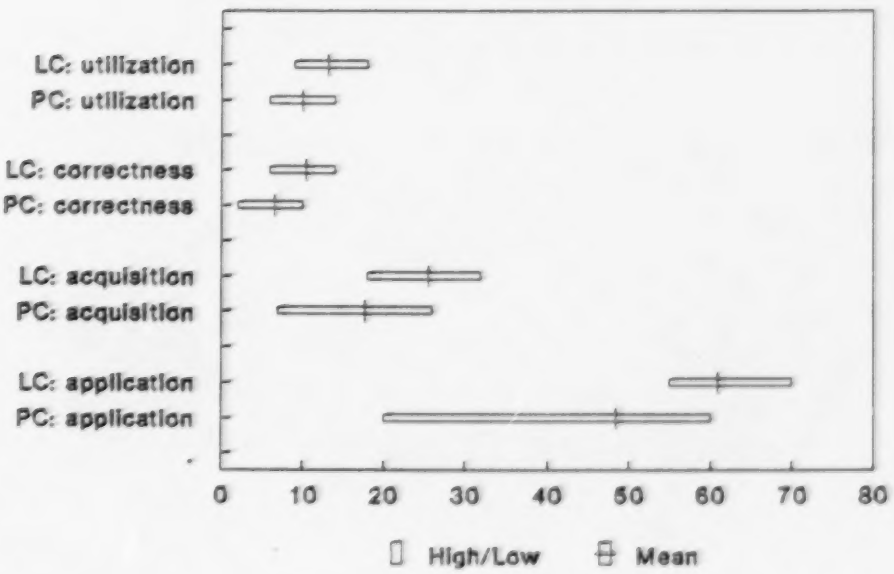
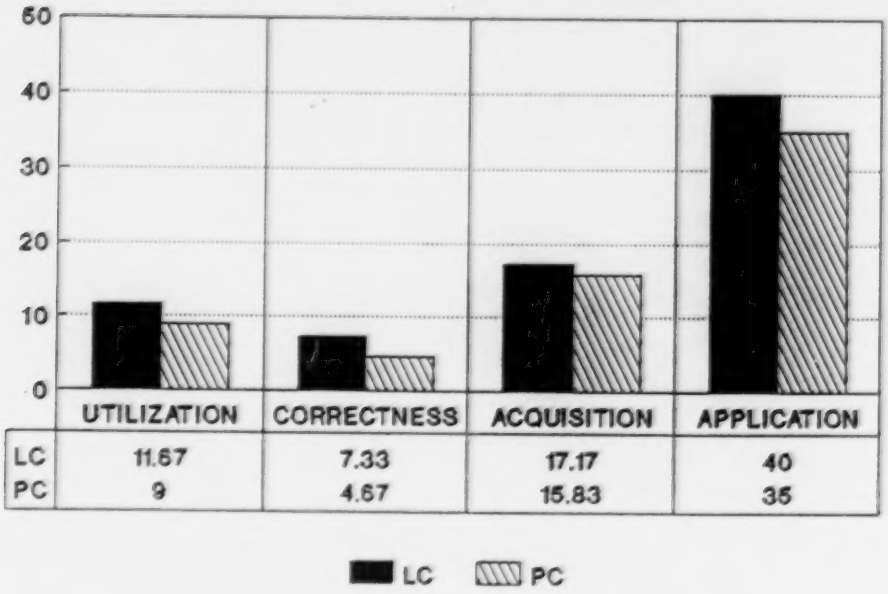


Table 7
LOW PRIOR Background knowledge GROUP
LEARNER CONTROL VS. PROGRAM CONTROL:
1) Means and Standard Deviations for Metacognition, Knowledge Acquisition and Knowledge Application
2) F Ratios and F Probabilities between the Treatment Groups

variables	control condition	mean	standard deviation	F Ratio	F Prob.
monitoring: utilization	lc	11.67	5.24	1.1636	.3060
	pc	9.00	5.24		
monitoring: correctness	lc	7.33	5.61	.9846	.3445
	pc	4.67	3.44		
knowledge acquisition	lc	17.17	7.39	.1321	.7238
	pc	15.83	5.12		
knowledge application	lc	40.00	19.75	.2083	.6478
	pc	35.00	18.17		

Note: lc = learner control treatment group
pc = program control treatment group

Figure 7.1
LEARNER CONTROL VS. PROGRAM CONTROL
LOW PRIOR BACKGROUND KNOWLEDGE GROUP



	UTILIZATION	CORRECTNESS	ACQUISITION	APPLICATION
LC	11.67	7.33	17.17	40
PC	9	4.67	15.83	35

Figure 7.2
LEARNER CONTROL VS. PROGRAM CONTROL
LOW PRIOR BACKGROUND KNOWLEDGE GROUP

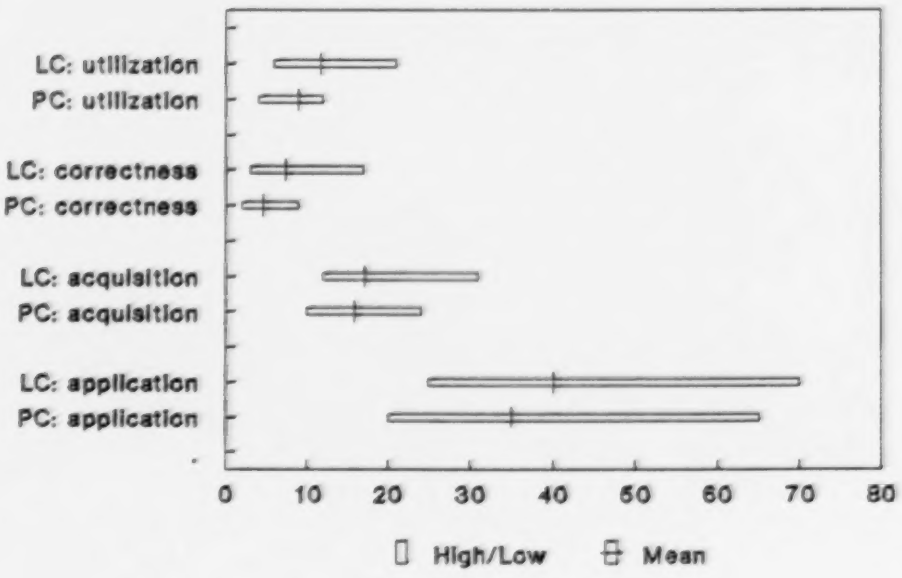


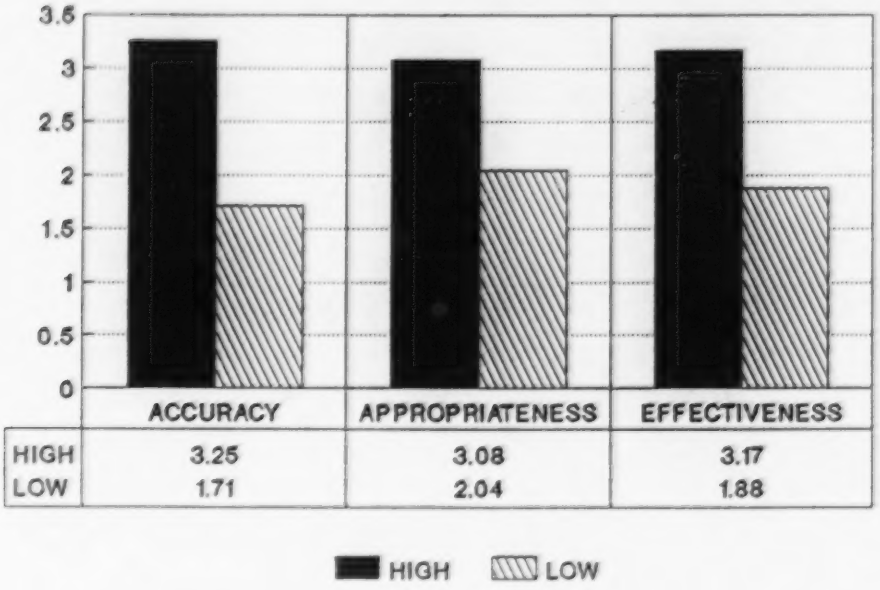
Table 8
HIGH VS. LOW PRIOR Background knowledge GROUPS
1) Means and Standard Deviations for Accuracy, Appropriateness and Effectiveness under Learner Control
2) F Ratios and F Probabilities between the Groups

variables	control condition	mean	standard deviation	F Ratio	F Prob.
accuracy	high	3.25	.45	37.0000	.0001 ***
	low	1.71	.45		
appropriateness	high	3.08	.77	7.8715	.0186 *
	low	2.04	.49		
effectiveness	high	3.17	.58	18.9173	.0014 **
	low	1.88	.44		

* p<.05
** p<.01
*** p<.001

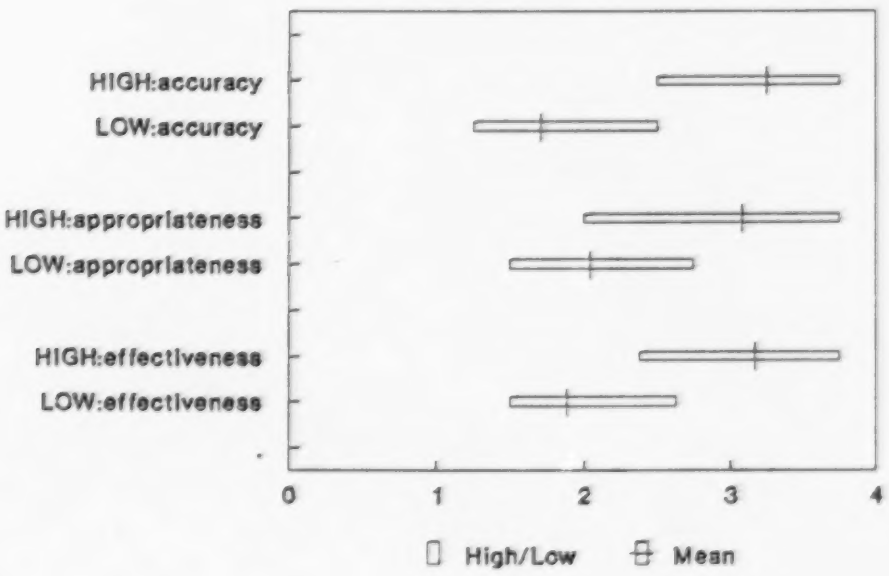
Note: high = high prior background knowledge group
low = low prior background knowledge group

Figure 8.1
HIGH VS. LOW PRIOR BACKGROUND KNOWLEDGE
ACCURACY, APPROPRIATENESS, EFFECTIVENESS



	ACCURACY	APPROPRIATENESS	EFFECTIVENESS
HIGH	3.25	3.08	3.17
LOW	1.71	2.04	1.88

Figure 8.2
HIGH VS. LOW PRIOR BACKGROUND KNOWLEDGE
ACCURACY, APPROPRIATENESS, EFFECTIVENESS



APPENDIX 2

ACCURACY OF SELF-ESTIMATES OF UNDERSTANDING

If SELF-EST="NOT AT ALL" & WRNO= 7 or 8, then ACCUR= 4.
If SELF-EST="NOT AT ALL" & WRNO= 5 or 6, then ACCUR= 3.
If SELF-EST="NOT AT ALL" & WRNO= 3 or 4, then ACCUR= 2.
If SELF-EST="NOT AT ALL" & WRNO= 1 or 2, then ACCUR= 1.
If SELF-EST="NOT AT ALL" & WRNO= 0, then ACCUR= 0.

If SELF-EST="A LITTLE" & WRNO= 7 or 8, then ACCUR= 2.
If SELF-EST="A LITTLE" & WRNO= 5 or 6, then ACCUR= 4.
If SELF-EST="A LITTLE" & WRNO= 3 or 4, then ACCUR= 3.
If SELF-EST="A LITTLE" & WRNO= 1 or 2, then ACCUR= 1.
If SELF-EST="A LITTLE" & WRNO= 0, then ACCUR= 0.

If SELF-EST="WELL" & WRNO= 7 or 8, then ACCUR= 0.
If SELF-EST="WELL" & WRNO= 5 or 6, then ACCUR= 1.
If SELF-EST="WELL" & WRNO= 3 or 4, then ACCUR= 4.
If SELF-EST="WELL" & WRNO= 1 or 2, then ACCUR= 3.
If SELF-EST="WELL" & WRNO= 0, then ACCUR= 2.

If SELF-EST="VERY WELL" & WRNO= 7 or 8, then ACCUR= 0.
If SELF-EST="VERY WELL" & WRNO= 5 or 6, then ACCUR= 1.
If SELF-EST="VERY WELL" & WRNO= 3 or 4, then ACCUR= 2.
If SELF-EST="VERY WELL" & WRNO= 1 or 2, then ACCUR= 3.
If SELF-EST="VERY WELL" & WRNO= 0, then ACCUR= 4.

SELF-EST: SELF-ESTIMATES OF ONE'S OWN UNDERSTANDING

WRNO: THE NUMBER OF WRONG ANSWERS IN A LESSON
(RANGE: 0 TO 8)

ACCUR: ACCURACY OF SELF-ESTIMATES OF UNDERSTANDING

APPROPRIATENESS OF THE USAGE OF CONTROL OPTIONS

If REVIEWNO - WRNO >= 0, then APPRO = 4.

If REVIEWNO - WRNO = -1 or -2, then APPRO = 3.

If REVIEWNO - WRNO = -3 or -4, then APPRO = 2.

If REVIEWNO - WRNO = -5 or -6, then APPRO = 1.

If REVIEWNO - WRNO = -7 or -8, then APPRO = 0.

REVIEWNO: THE NUMBER OF REVIEW OPTIONS USED

WRNO: THE NUMBER OF WRONG ANSWERS IN A LESSON
(RANGE: 0 TO 8)

APPRO: APPROPRIATENESS OF THE USAGE OF CONTROL OPTIONS

EFFECTIVENESS OF THE USAGE OF CONTROL OPTIONS

EFFECTIVENESS = (ACCUR + APPRO) / 2

ACCUR: ACCURACY OF SELF-ESTIMATES OF UNDERSTANDING

APPRO: APPROPRIATENESS OF THE USAGE OF CONTROL OPTIONS

APPENDIX 3

QUESTIONS AND PROMPTS ADAPTED FROM THE METACOMPONENTIAL INTERVIEW:

QUESTION #1:

When Albert was 6 years old, his sister was 3 times as old as he.

Now he is 10 years old and he figures that his sister is 30 years old.

How old do you think his sister will be when Albert is 12 years old?

PROMPTS:

1. Do you have to watch out for mistakes when you do this problem?
2. Is there something in the problem that could trick you if you were not careful?
3. Is Albert right when he figures that when he is 10 years old his sister is 30 years old?
4. Will his sister always be 3 times as old as Albert?
   Is that a mistake? Should you multiply or add years?
5. Don't make a mistake.
   When Albert was 6, his sister was 18.
   12 years older.
   What would his sister be 1 year later, when Albert was 7 ?
   (19) 12 years older. One year later?
   (Continue if child does not understand, until solve 10/22 problem of Albert's.)

QUESTION #2:

Every classroom in Mary's school will have
2 girls for every boy.

Mary found out that there will be 8 girls
in her class, so she figured
there would be 16 boys.

Her sister's class will have 10 girls.

How many boys do you think will be
in her sister's class?

PROMPTS:

1. Do you have to watch out for mistakes
   when you do this problem?
2. Is there something in the problem
   that could trick you if you were's careful?
3. Is Mary right when she figures that
   there will be 16 boys in her class?
4. Will a classroom with 2 girls for every boy
   have 2 times as many boys?
   Is that a mistake? Or half as many boys?
5. Be careful not to make a mistake.
   If there were 2 girls, and there are 2 girls
   for every boy, then there would be 1 boy.
   Half as many boys.
   If there were 4 girls, then there
   would be 2 boys.
   Half as many boys.
   (Continue if child does not understand
   until the 8/4 problem of Mary's is solved.)

QUESTION #3:

At our school the track is in a circle with six flags spaced equally around it.

Yesterday, Frank started at the first flag and raced around the circle.

He took 2 minutes to get to the third flag.

He thought it would take him 2 more minutes to get to the sixth flag if he kept on at the same rate.

How long did it take him to get all of the way around the track?

PROMPTS:

1. Do you have to watch out for mistakes when you do this problem?
2. Is there something in the problem that could trick you if you were not careful?
3. Is Frank right when he figures that it would take him 2 more minutes to get to the sixth flag?
4. Is it the same distance from the first to the third as from the third to the sixth flag? Is that a mistake? Where does he start? How many flags is it to the third flag starting at the first flag?
5. Don't make a mistake. Pretend Frank starts at the first flag, then goes to the second, then the third flag. That takes him 2 minutes. How long will it take him to get to the fourth, then the fifth flag? (The sixth?)

QUESTION #4:

Betty used to weigh 32 pounds
standing on one foot.

Frank said she would have weighed
64 pounds standing on both feet.

Now Betty weights 40 pounds standing on one foot.

How much do you think she weighs now
standing on both feet?

PROMPTS:

1. Do you have to watch out for mistakes
   when you do this problem?
2. Is there something in the problem
   that could trick you if you were not careful?
3. Is Frank right when he figures that Betty would
   weigh 64 pounds standing on both feet?
4. Will people always weigh twice as much
   standing on 2 feet as they do standing
   on 1 foot?
   Is that a mistake?
   Does that change what they would weigh?
5. Don't make a mistake.
   Would you get heavier standing on 1 foot,
   then 2 feet, then maybe on your hands and feet?
   Does that change how much you weigh?

END

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